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The investigation of this sharply defined strychnine-compound, which can be preserved for months without undergoing any decomposition, goes far to prove the existence of a persulphide of hydrogen,



it is, however, by no means improbable that compounds of hydrogen and sulphur in several proportions may exist.

The formation of the strychnine-compound which I have described, and which I have often prepared with the same result, could not fail to lead to an examination of several other alkaloids in a similar direction. Quinine, cinchonine, brucine, and several other vegetal bases were repeatedly submitted to the action of an alcoholic solution of polysulphide of ammonium, but in no case were similar phenomena observed.

The compound of strychnine with persulphide of hydrogen is remarkable for its insolubility. An alcoholic solution containing 2·03 grs. of strychnine, when mixed with an alcoholic solution of polysulphide of ammonium and allowed to stand for twelve hours, was found to have deposited 2·287 grs. of the red crystals, *i. e.* 87·2 per cent. of the theoretical amount. It deserves to be examined, whether the property possessed by strychnine, of forming so insoluble a compound with persulphide of hydrogen, could not be utilized for the purpose of preparing this alkaloid, and in certain cases even for its detection and separation from other substances with which it might be mixed.

II. "Note on the Anatomy of the Blood-vessel System of the Retina of the Hedgehog." By J. W. HULKE, F.R.S. Received May 26, 1868.

(Abstract.)

This retina is very remarkable for the fact that all the arteries and veins lie upon the inner surface of the membrana limitans interna retinæ, in intimate relation with the membrana hyaloidea; while capillaries only traverse the limitans, receiving a sheath from it, and penetrate the inner layers of the retina. The hedgehog's retina is in this respect a link between the non-vascular retina of fish, amphibia, reptiles and birds, and the vascular retinæ of most mammals.

III. "Researches on Refraction-Equivalents." By J. H. GLADSTONE, Ph.D., F.R.S. Received May 29, 1868.

Since the paper of the Rev. T. Pelham Dale and myself "On the Refraction, Dispersion, and Sensitiveness of Liquids"*, our researches have been continued from time to time, and a good deal of attention has been paid to the subject in Germany. The permanence of the specific refractive

* Philosophical Transactions, 1863, p. 317.

energy of a body, notwithstanding change of temperature, aggregate condition, solution, or even chemical combination, has been confirmed, and upon this has been built the doctrine of Refraction-equivalents.

Our "specific refractive energy" is the refractive index of any substance minus unity, divided by the density; in symbolic language $\frac{\mu-1}{d}$. Professor Landolt's "Refraction-equivalent" is the same multiplied by the chemical equivalent, or $P \frac{\mu-1}{d}$.

The largest generalization arrived at is that the refraction-equivalent of a compound is the sum of the refraction-equivalents of its constituents. This has been sufficiently proved in a multitude of instances among the compounds of carbon, hydrogen, and oxygen, and it has been shown, or assumed to be the case, in the combinations of many other elementary bodies*.

My more recent researches have branched off into several lines, but an especial attempt has been made to answer the following questions. Have any of the elements more than one definite refraction-equivalent? and what are the refraction-equivalents of the metallic elements? A large mass of observations bearing on these points has been gathered together, and more or less collated, but it is yet imperfect, and my present object is rather to indicate the principal method of inquiry than to publish the actual results.

As the metals are opaque, their refractive indices cannot be determined in a direct manner as those of gaseous hydrogen, liquid phosphorus, crystallized carbon, and other transparent elements have been. An attempt must therefore be made to determine their effect on the rays of light by examining their compounds; but their crystalline salts are very frequently doubly refracting, owing to some peculiarities of internal structure, and, where they give only one spectrum, there are practical difficulties about the experiment that are not encountered in dealing with liquid bodies. The solutions of these salts have only one refraction, and it occurred to me that they might afford an easy means of determining the refraction-equivalents, first, of the compounds themselves, and secondly, of their metallic and other constituents. In practice, many sources of error presented themselves, all of which tell upon the ultimate result, and which necessitated improved apparatus, and great care both in preparing the solutions and in taking the observations.

The method generally adopted was as follows:—An amount of salt representing the chemical equivalent was dissolved in n equivalents of water,

* See Brit. Association Report, 1863, Transactions of Sections, p. 12. Ibid. 1866, p. 37. Journal of the Chemical Society, ser. 2, vol. iii. p. 108. Landolt, Pogg. Annalen der Physik und Chemie, vols. cxvii., cxxii., and cxxiii. Ketteler, Ueber die Farbenzerstreuung der Gase, 1865. Haagen, Pogg. Annalen, vol. cxxiii. p. 125. Schrauf, Pogg. Annalen, vol. cxxvii. p. 344. Wüllner, Pogg. Annalen, vol. cxxxiii. p. 1.

and the refractive index and density of the solution were taken. From these was reckoned the refraction-equivalent, and subtracting from this n times the refraction-equivalent of water for the solar line A, there remained the refraction-equivalent of the dissolved salt for that part of the spectrum. That this fairly represents the action exerted on light by the chemical compound itself is supported by several considerations. 1st. In the few cases, such as chloride of sodium and sugar, where the refraction-equivalent of the substance has been obtained, both in the solid and dissolved condition, it is found to be the same. 2nd. Solutions of several organic substances, such as formic and citric acids, give the theoretically correct equivalent for these substances. 3rd. The refraction-equivalent of a salt seems to be the same, whether it be dissolved in water or in alcohol. 4th. The refraction-equivalent of a salt in solution is not affected by altering the amount of water in which it is dissolved. 5th. The numbers reckoned for these salts in solution bear such a remarkable relation to one another as to force the conviction that they are made up of two components, the one depending on the metal, the other on the substance combined with it. To exhibit the nature and force of this argument, it would be necessary to tabulate a long series of results; but for the present I shall confine myself to the salts of potassium and sodium with the corresponding hydrogen compounds.

Dissolved compound.	Common formula.	Refraction-equivalents.			Difference between potassium and sodium compounds.	Difference between potassium and hydrogen compounds.
		Potassium compound.	Sodium compound.	Hydrogen compound.		
Chloride.....	MCl	18.44	15.11	14.44	3.3	4.0
Bromide	MBr	25.34	21.70	20.63	3.6	4.7
Iodide	MI	35.33	31.59	31.17	3.7	4.2
Cyanide.....	MNC	17.12	.....	.....	.....	.....
Sulphocyanide	MSNC	33.40	.....	.....	.....	.....
Nitrate	MNO ₃	21.80	18.66	17.24	3.1	4.5
Metaphosphate	MPO ₃	.....	19.48	18.68	.....	.....
Hydrate.....	MHO	12.82	9.21	5.95	3.6	6.8
Alcoholate.....	MC ₂ H ₅ O	27.68	24.28	20.89	3.4	6.8
Formiate	MCHO ₂	19.93	16.03	13.40	3.9	6.5
Acetate	MC ₂ H ₃ O ₂	27.65	24.05	21.20	3.6	6.5
Tartrate.....	M ₂ C ₄ H ₄ O ₆	57.60	50.39	45.18	3.6	6.2
Carbonate	M ₂ CO ₃	34.93	28.55	.....	3.2	.....
Sulphate	M ₂ SO ₄	30.55	26.20*	22.45	2.2	4.1
Bichromate	M ₂ Cr ₂ O ₇	79.9	72.9	.....	3.5	.....
Hypophosphite.....	M ₂ PH ₂ O ₂	26.94	20.93	.....	3.0	.....

From the above numbers several conclusions may be safely drawn. First,

* This number seems to be too high, but it is the mean of fairly accordant results. It is rejected in the calculation of average difference between potassium and sodium.

it is evident that the refraction-equivalents of the compounds of potassium differ very widely according to the nature of the electro-negative constituents ; again, that the refraction-equivalents of the compounds of sodium differ *pari passu* with those of the potassium compounds, being always less by a number varying from 3·0 to 3·9. From this it may be fairly concluded that the electro-negative constituent has the same effect on light, whichever metal it is united with, and that the refraction-equivalent of potassium exceeds that of sodium by 3·4, or thereabouts. But does the Table afford the data for determining the absolute equivalent of one or other of these metals ? It was at first thought that this would be arrived at by a comparison of the metal with hydrogen, the refraction-equivalent of which has hitherto been estimated at 1·3 (or 1·5 in the case of water) ; but the last column shows that the difference between potassium and hydrogen is not always the same, the differences being greater than can be attributed to errors of observation. Indeed the numbers seem to fall into two groups : with the mineral acids the differences lie between 4·0 and 4·7, while with water, alcohol, and the organic acids, they are always upwards of 6, varying indeed from 6·2 to 6·8, the average being 6·55. But it is in these last-mentioned compounds that the equivalent of hydrogen is believed to be 1·3. Assuming this, we may reckon the refraction-equivalent of potassium to be about 6·55 + 1·3, that is, 7·85. We have, however, other means of arriving at an estimation. Chlorine, in such bodies as chloroform or tetrachloride of carbon, is represented by 9·8. Again, cyanogen, from the experiments of Dulong on the gas itself, may be taken at 9·2 Sulphur has a refraction of 16·0 ; hence sulphocyanogen may be reckoned as 16·0 + 9·2, that is, 25·2. Subtracting these numbers from those of the respective potassium salts, we obtain the equivalent of the metal. Thus from different sources we may calculate for the value of potassium :—

From the chloride	8·6
,, cyanide.....	7·9
,, sulphocyanide	8·2
,, hydrate.....	8·3
,, alcoholate.....	8·1
,, formiate	7·8
,, acetate	7·7
,, tartrate.....	7·5

These numbers are tolerably close, though the equivalent of potassium, deduced from its inorganic, would, on the whole, be higher than that deduced from its organic compounds. The mean of the first four computations is 8·2, that of the last four 7·8. Perhaps, pending further researches, it will be best to assume the mean of these numbers,

$$\text{Potassium} \dots \dots \dots = 8\cdot 0;$$

and since a sodium salt has a refraction-equivalent generally 3·4 lower than the corresponding potassium salt, we may reckon

$$\text{Sodium} \dots \dots \dots \dots \dots = 4\cdot6^*.$$

If instead of taking the refraction-equivalent $P \frac{\mu-1}{d}$, we reckon the specific refractive energy $\frac{\mu-1}{d}$, we obtain the following values :—

Potassium	.....	0·205
Sodium	.....	0·200

This implies that equal quantities of these two analogous metals exert very nearly, if not precisely, the same effect on the velocity of the rays of light.

Another deduction from the above Table is that already alluded to in regard to hydrogen ; while in the organic acids it probably has the known refraction-equivalent 1·3, it would seem that in the others, viz. hydrochloric, hydrobromic, hydriodic, nitric, metaphosphoric, and sulphuric acids, it has a very much higher refraction-equivalent, one in fact which is little less than sodium, and falls short of potassium by only about 4·3. Hence we may we deduce—

$$\begin{aligned}\text{Hydrogen in organic compounds} & \dots \dots = 1\cdot3 \\ \text{Hydrogen in mineral acids} & \dots \dots = 3\cdot7\end{aligned}$$

How far this conclusion may hold good throughout, and whether one number should be an exact multiple of the other number, must remain to be determined by future observations. It appears, however, to answer in the affirmative the question whether an element can have more than one definite refraction-equivalent.

Of course, from the Table given above, it would be easy to deduce values for each of the electro-negative constituents ; but it would be safer to generalize from a larger number of instances.

The series of observations on potasism and sodium salts are the most complete and the most carefully revised of any which have yet been made ; but if their refraction-equivalents are fixed, it becomes a much simpler matter to determine those of most other metals. Thus, of lead the nitrate and acetate have alone been examined ; but as the refraction-equivalents reckoned for these salts differ from those of the corresponding potassium compounds in each instance by 4·1, the presumption is great that the refraction-equivalent of lead is very near 8·0+4·1, or 12·1.

The following are numbers deduced from two or more salts of each metal. They must be looked upon only as approximately true, and any subsequent modification of the value 8·0 for potassium, must lead to a corresponding modification of the whole series.

* Haagen, from the crystalline chloride, determined the refraction-equivalent of sodium for the hydrogen line d at 4·89.

Metal.	Chemical equivalent.	Refraction-equivalent.	Specific refractive energy.
Potassium	39	8·0	0·205
Sodium	23	4·6	0·200
Lithium.....	7	3·9	0·557
Magnesium	12	3·7	0·308
Barium	68·5	7·8	0·114
Strontium	43·8	6·5	0·148
Calcium.....	20	5·2	0·260
Zinc	32·6	4·8	0·147
Nickel	29·5	5·1	0·173
Cobalt	29·4	5·2	0·177
Lead	103·5	12·1	0·117
Mercury	100	9·8	0·098
Ammonium	18	11·4	0·633

These numbers are suggestive in many ways; but I will only remark the very high refractive energy of lithium, the practical identity of nickel and cobalt, and the remarkable fact that the specific refractive energy of the metals are (with one or two exceptions) in the inverse order of their atomic weights.

IV. "A Third Memoir on Skew Surfaces, otherwise Scrolls." By Prof. CAYLEY. Received May 30, 1868.

(Abstract.)

The present Memoir is supplementary to my "Second Memoir on Skew Surfaces, otherwise Scrolls," Phil. Trans. vol. cliv. (1864) pp. 559–577, and relates also to the theory of skew surfaces of the fourth order, or quartic scrolls. It was pointed out to me by Herr Schwarz, in a letter dated Halle, June 1, 1867, that in the enumeration contained in my Second Memoir I have given only a particular case of the quartic scrolls, which have a directrix skew cubic; viz. my eighth species, $S(1, 3^2)$, where there is also a directrix line. And this led me to observe that I had in like manner mentioned only a particular case of the quartic scrolls with a triple directrix line; viz. my third species, $S(1_3, 1, 4)$, where there is also a simple directrix line. The omitted species, say, *ninth species*, $S(1_3)$, with a triple directrix line, and tenth species, $S(3^2)$, with a directrix skew cubic, are considered in the present Memoir; and in reference to them I develop a theory of the reciprocal relations of these scrolls, which has some very interesting analytical features.

The paragraphs of the present Memoir are numbered consecutively with those of my Second Memoir above referred to.